UNIV. OF MARY.

BULLETIN

OF

THE JOHNS HOPKINS HOSPITAL

Entered as Second-Class Matter at the Baltimore, Maryland, Postoffice
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917. Authorized on July 3, 1918.

Vol. XXX—No. 336] BALTIMORE, FEBRUARY, 1919 [Price, 50 Cents

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FLUOROSCOPY OF THE CEREBRAL VENTRICLES

By Walter E. Dandy

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In a recent communication,[1] it was shown that if air is substituted for the cerebrospinal fluid in the ventricles of the brain, an accurate outline of the lateral ventricles will be cast in a roentgenogram. This offspring of radiography, which we have called pneumoventriculography or ventriculography, has already proved of great value in the diagnosis and localization of many intracranial lesions which without its aid would either have been overlooked or incorrectly localized.

Heretofore, shadows have been produced in the gastro-intestinal and genito-urinary tracts and elsewhere by the introduction of solutions or suspensions offering a particular resistance to the penetration of the X-rays. The injection of any such media into the ventricles of the brain is, however, absolutely precluded on account of injury to the brain and because their elimination is impossible; and even if it were permissible to inject them into the ventricles, the specified substances would not yield shadows so striking as those obtained in abdominal work.

The distinctness of an X-ray shadow is emphasized by contrast. The abdominal wall, composed of soft, easily penetrable and light shadow-casting tissues, emphasizes the dense shadows cast by resistant media.

The skull shadow is, however, so dense that it would subdue the outlines of shadows cast by any resistant fluid media which might be injected into the ventricles. Against a background of skull and brain shadow, the air-filled ventricle is sharply outlined. Air has proven so satisfactory in every way that we have as yet seen no need of substituting other gases for it, though it is possible that a gas, such as hydrogen (with the lowest density), might produce an even more distinct shadow.

Recently, at the suggestion of Dr. J. William Pierson, these X-ray studies have been amplified by observations under the fluoroscope. The results have been equally striking. The ventricles are outlined just as distinctly as in the X-ray plate. From a series of over 75 cases from Professor Halsted's clinic, in which air has been introduced into the ventricles, 20 have had fluoroscopic studies in addition to the X-ray plates. The ages of the patients examined under the fluoroscope have ranged from three months to 55 years. The ventricles were almost as distinct in adults as in infants and young children, though stronger rays were necessary to penetrate the thicker skulls. The size of the ventricles has ranged from normal to the extreme grades of dilation in advanced hydrocephalus. From 20 to 350 c. c. of air have been introduced into the ventricles.

Just as in fluoroscopic and X-ray studies elsewhere, each method has certain advantages not possessed by the other. The value of each is in large part supplementary, and the best results are therefore obtained by combining the salient advan-

[1] Dandy, W. E.: Ventriculography Following the Injection of Air into the Cerebral Ventricles. Ann. Surg., July, 1918.

tages of each. A fluoroscopic study of the cerebral ventricles yields the same results as a series of ventriculograms. Either profile or anteroposterior views of any part of one or both lateral ventricles can be obtained under the fluoroscope at will by the proper movement of the head. Every part of both lateral ventricles can be systematically observed during a single examination. In this way, the result will be a composite picture of the ventricular system. Fluoroscopic studies, however, lack the graphic and permanent record of the ventriculogram. The interpretations at a fluoroscopic examination are necessarily dependent upon transient and hasty impressions which make the personal equation too prominent in questions of doubt, particularly when the observer's experience is limited, and especially at the present time when at best our knowledge of the normal and the pathological is uncertain.

The technique of the air injection has been described elsewhere. In over 75 cases no deleterious results have occurred. At times slight symptoms of intracranial pressure develop, but quickly subside on release of the air by ventricular puncture.

Procedure for Fluoroscopic Examination

Fluoroscopic rays passing through a normal or a hydrocephalic head show nothing to the observer except a homogeneous dark mass of the head, with slight accentuation of the bony landmarks. There is not sufficient difference between the density of cerebrospinal fluid and normal or pathological cerebral tissue to make any differential impression on the rays, regardless of the proportion of these constituents. When air is injected into the ventricles the reduction in density is so great that the ventricles stand out as a clear zone in strong relief against this dark background. The contrast is almost as striking as that seen under the fluoroscope when bismuth or barium is introduced into the stomach.

The usual fluoroscopic equipment contains a separate apparatus for vertical and horizontal rays. When the vertical rays are used, the patient is placed in the recumbent position. When horizontal rays are used, the patient must be sitting or standing. *For ventricular fluoroscopy the vertical rays and the recumbent position* yield the most important results. Horizontal rays and the sitting posture are less satisfactory because the dependent part of the ventricle contains fluid, this giving the ventricle a horizontal bisected appearance (Fig. 1). Only the upper part of the ventricle is then visible. When the patient is recumbent and the head is on the side, a full profile view of one ventricle is obtained because all the fluid has passed to the dependent ventricle.

The horizontal rays, utilizing the sitting posture, are very useful to demonstrate the movements of air in the ventricle and to understand the necessary positions to be assumed in shifting air from one terminus of the ventricular system to the other. When the head is at rest in this position, a line of demarcation is evident at the dividing line between fluid and air (Fig. 3). Each movement of the head temporarily disturbs this fluid level, which quickly reforms with rest, just as in hydropneumothorax. Since only part of the fluid in the ventricles is usually replaced by air, it is evident that the position of the head will determine the part of the ventricular system that will contain air or fluid at a given time. The movement of air and fluid in hydropneumothorax is simple, because there is a single large cavity. To move the air from one part to another of the ventricular system is more difficult owing to the curves, angles and branches of the lateral ventricles and to the points of narrowing at the foramina. Moreover, since the lateral ventricles are paired and communicate only anteriorly through the small foramina of Monro, these difficulties become greater. Beginning with a small amount of air in the descending horn of one lateral ventricle, by changing the position of the head one can observe the air passing into the posterior horn, then the body, the anterior horn, through the foramen of Monro into the third ventricle. From the third ventricle it passes through the opposite foramen of Monro into the opposite lateral ventricle and by reversing the movements of the head the air may be sent to the descending horn of this ventricle. The necessary movements are best understood by visualizing the ventricular system in three dimensions. Needless to say, since air is lighter than fluid, its movement in the ventricle is in the direction opposite to the movement of the head, or the reverse of gravity of fluid.

The rapidity of transfer of fluid from one lateral ventricle to the other varies with the size of the foramina of Monro. In advanced hydrocephalus much additional communication between the lateral ventricles results from large perforations in the septum lucidum due to absorption from increased intraventricular pressure. Up to a certain stage the size of the foramina of Monro is proportionate to the size of the ventricles. After additional communication following rupture of the septum lucidum, increase in size of the foramina of Monro ceases. In normal or slightly enlarged ventricles the air passes from one lateral ventricle to the other only when the position of the head is such (occiput down) that all the air is in the anterior horn. If the head is then turned toward the side containing the air, air passes through the interventricular foramina to the opposite lateral ventricle. When the interventricular septum is destroyed, the air rushes rapidly through these artificial openings from one lateral ventricle to the other without regard to the anteroposterior position of the head. This can be observed under the fluoroscope in the anteroposterior view either with the vertical or horizontal rays.

In normal or moderately enlarged ventricles there is an uneven distribution of air in the two lateral ventricles when viewed anteroposteriorly. Only in large ventricles with very large foramina of Monro or in which there are artificial openings in the septum lucidum, is the communication between the lateral ventricles ample to give an equal distribution of air on the two sides without careful manipulations of the head. In a lateral view, with the patient sitting, two superimposed levels of air and fluid—one for each ventricle—can be seen when the head is tilted to one side. In advanced hydrocephalus, the two cavities are practically fused into a single space, so that the fluid in the two sides quickly assumes the same level.

FIG. 1.—Drawing by Miss Norris to show the fluoroscopic picture of a lateral ventricle in a case of advanced hydrocephalus. Note the false ventricular hernia caused by a local rupture of the thinned cortex over the anterior fontanelle (Fig. 9). The diagnosis of hydrocephalus and of the direct connection of the swelling with a lateral ventricle were made only by the fluoroscope and pneumoventriculography.

FIG. 2.—Anteroposterior view of same ventricular hernia. The sac communicates with only one lateral ventricle. The degree of enlargement of the ventricles can be accurately determined from this view. Figs. 1 and 2 are viewed in the recumbent posture and therefore vertical rays are used.

FIG. 3.—Profile view of lateral ventricle of same case (Figs. 1 and 2), but the patient is sitting and horizontal rays are used. The lower part of the ventricle does not show, because in this posture it is filled with fluid (due to gravity). Note the sharp horizontal line of demarcation at the fluid-air level. The ventricular hernia shows as well as in the previous figures because it is uppermost.

FIG. 4.—Same as Fig. 3, except head is tilted slightly to one side, thus showing the two levels of fluid (*A* and *B*); one fluid level for each lateral ventricle. In ventricles as large as these the communication between the two lateral ventricles is so free, because of artificial openings in the septum lucidum, that these two levels of fluid are only transient. The levels soon merge regardless of the anteroposterior position. In smaller ventricles the two levels remain, but of course are superimposed when the position of the head is exactly vertical.

FIG. 5.—Showing the transfer of air to anterior part of lateral ventricles when the head is bent backward. The horizontal fluid level remains in all cases in which horizontal rays and vertical positions are used.

FIG. 6.—To show distribution of fluid when the head is bent forward. Note that most of the air is now in the posterior part of the lateral ventricle, but the fluid level is such that the sac and the neck of the sac are partly filled with air. With a little more tilting of the head forward, the sac would contain only fluid.

FIG. 7.—Anteroposterior view. Showing transfer of fluid from one lateral ventricle to the other. When the head is tilted to one side, the amount of air which crosses depends entirely upon the angle assumed. When the head is bent to a horizontal line all the air will be in the upper ventricle.

FIG. 8.—Photographs of child with swelling over anterior fontanelle. The black lines mark the limits of the fontanelle.

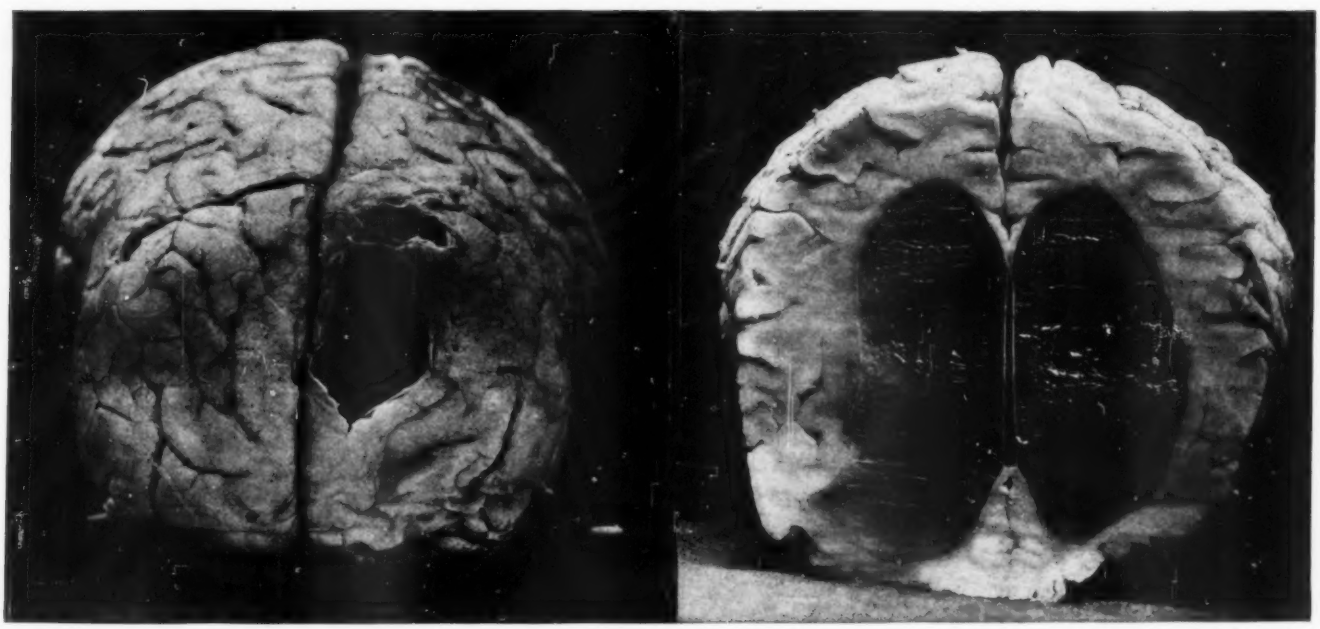


FIG. 9.—(A) View from above of brain from which preceding fluoroscopic studies were made. Note the rupture in the cortex through which the cerebrospinal fluid passed into the swelling in the scalp. The fluid remained localized owing to the adhesions which formed around the opening.

(B) Section of same brain to show size of lateral ventricles. Despite the great size of ventricles, the head was only slightly enlarged.

PRACTICAL RESULTS FOLLOWING FLUOROSCOPY

In this series of cases the results from fluoroscopic study have been practically the same as from ventriculography. Many cases of hydrocephalus have been studied with or without other complicating conditions. Either by ventriculography or fluoroscopy the dilated ventricles are pathognomonic. In many cases a positive diagnosis could not have been made in any other way. In several cases the ventricles were normal or nearly so.

A very interesting case was reported to me by Dr. Blackfan from Professor Howland's clinic. A child five months old was brought into the hospital because of a lump over the anterior fontanelle. The swelling was about as large as a walnut, was soft and fluctuant. It was situated just to the left of the midline. The head was slightly large and the anterior fontanelle wider than normal. The diagnosis of meningocele seemed most probable. A fluoroscopic study with air in the ventricles at once made an unusual diagnosis clear. The interior of the swelling was in direct continuity with a lateral ventricle. The air could be made to enter or depart at will by suitable manipulations of the head. In the anteroposterior views this swelling could be seen to connect with one ventricle only. In addition to the ventriculocele, or false ventricular hernia, was an advanced hydrocephalus, suspected, but demonstrated only by fluoroscopy or ventriculography. At necropsy the findings were substantiated. Following a local area of atrophy in the cortex, the ventricular wall had ruptured and the fluid had become encapsulated by being walled off in the scalp. In the accompanying figures (Figs. 1 to 7) this case has been used to demonstrate the movements of air in the ventricles resulting from change of position of the head.

A second patient was a boy of 12, blind from intracranial pressure. The diagnosis could not be agreed upon. Cerebellar tumor with obstructive hydrocephalus, oxycephalus, and communicating hydrocephalus were the final divergent diagnoses reached. A discussion of the differential diagnosis would be irrelevant here, except to indicate that by fluoroscopy of the ventricles and by ventriculography an advanced hydrocephalus was demonstrated. This excluded so-called oxycephalus. Though hydrocephalus had been proven, the differential diagnosis between the obstructive and communicating types of hydrocephalus cannot at present be made positively either by ventriculography or fluoroscopy. A cerebellar exploration failed to disclose a tumor. The phenolsulphonepthalein test excluded tumor and made an absolute diagnosis of communicating hydrocephalus.

In a third case hydrocephalus was diagnosed by fluoroscopy, in a child five days old, with a normal-sized head. Hydrocephalus was suspected by Dr. J. Whitridge Williams at birth because the fontanelles were wide. A lumbar meningocele with paraplegia was also suggestive. By fluoroscopy a well-advanced dilation of the ventricles was demonstrated.

In a fourth case a transcortical operation had been made into the lateral ventricle some time previously. In the fluoroscope the operative defect could be observed as a pouch from the already dilated ventricle. A fifth case had an advanced grade of hydrocephalus. The diagnosis was evident from the enlarged head, so that fluoroscopy was of interest more than of practical value. The large head was almost entirely filled with fluid; the septum lucidum was destroyed so that the two lateral ventricles were practically a single cavity with little indication of their former shape. In three cases recovering from meningitis hydrocephalus was diagnosed by the moderate ventricular enlargement which was visible under the fluoroscope. In none of these was hydrocephalus suspected, though the lethargy and stupor of the children indicated some intracranial complication.

Fluoroscopy has as yet been employed only in a limited number of conditions. Several times we have seen air in the cisterna magna indicating the patency of all the ventricular foramina but have not yet observed its passage through the aqueduct of Sylvius and fourth ventricle. It should be possible to demonstrate dislocation or partial obliteration of one or both ventricles from tumor pressure and thus help to localize the tumor. The rare cases of unilateral hydrocephalus with occlusion of the foramen of Monro should also be diagnosed by the unilateral ventricular dilatation and by the absence of communication between the ventricles of the two hemispheres. In this condition the difference in size of the two ventricles could be determined only by making a separate injection of air into each lateral ventricle.

The normal-sized ventricles have been observed in an adult and two children. Aside from the difference in size of the ventricles the air passes from one side to the other much more slowly, and more careful manipulations of the head are necessary to accomplish the transfer.

CONCLUSIONS

1. The lateral cerebral ventricles, when filled with air, can be clearly seen under the fluoroscope; 25 cases have been studied by this method.

2. The results in adults are equally as good as in children.

3. By fluoroscopy hydrocephalus can be accurately diagnosed at all stages of its development.

4. Several unsuspected cases of hydrocephalus have been demonstrated by the fluoroscope.

5. The diagnosis of a false ventricular hernia (ventriculocele) was made with certainty, because the air from the ventricle could be seen to pass directly into the swelling.

6. Fluoroscopy of the ventricles has practically the same range of utility as ventriculography, and almost the same results have been obtained. Following the injection of air into the ventricles, both fluoroscopy and ventriculography should be used.

STEREOROENTGENOGRAMS OF THE INJECTED LUNG AS AN AID TO THE STUDY OF THE LUNG ARCHITECTURE

By William Snow Miller

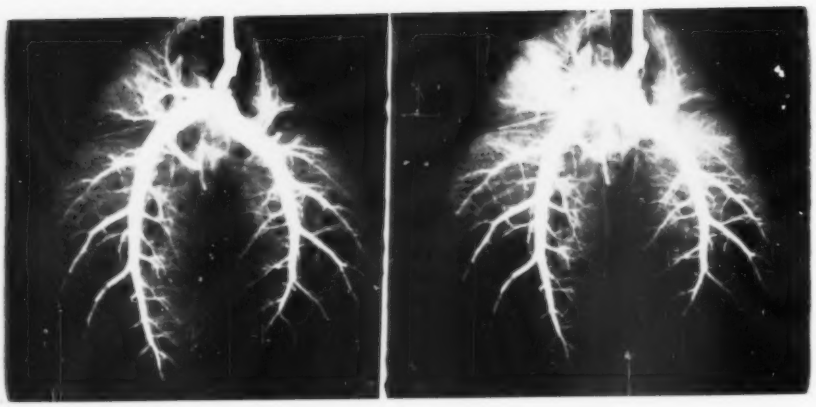
(From the Kenneth Dows Fund for the Study of Tuberculosis, of the Medical Clinic of The Johns Hopkins Hospital and University, Baltimore, Md.)

In a previous communication I have given the general directions for the preparation of a differential injection mass which is especially applicable to the study of the distribution of the blood-vessels within the lung by means of stereoroentgenograms, for it clearly brings out their relation to the bronchi, to each other, and to the lobation of the lung. The basis of the injection mass consists of a suspension of cornstarch in 70 per cent alcohol, to which vermilion granules are added when it is desired to obtain a uniform dense shadow, and ultramarine blue granules when a less dense and finely granular shadow is desired as a differential injection mass. By the use of a greater or less quantity of the 70 per cent alcohol the injection masses may be made to penetrate to any desired distance within the lung. If the bronchi alone are to be injected a thick vermilion mass gives the best results; for if the mass be too thin it will penetrate the air sacs and a blurred shadow will result, or else the whole lung will appear solid.

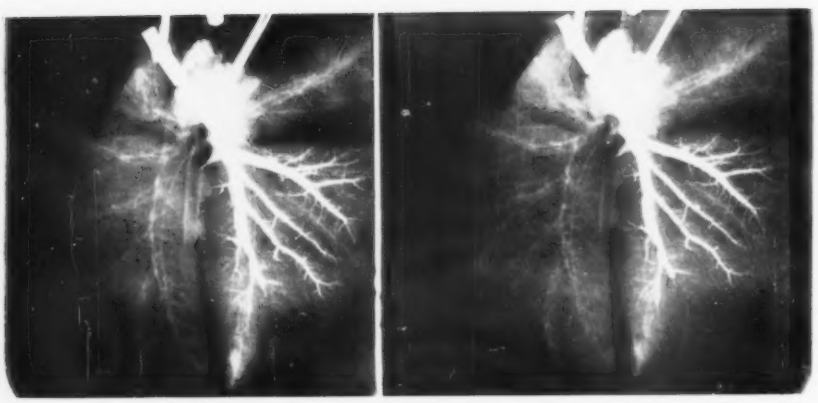
The relation of the pulmonary artery, the pulmonary vein, and the bronchi to each other can be summarized as follows: The pulmonary artery follows in all of its subdivisions the subdivisions of the bronchial tree. As each main branch of the pulmonary artery arches over its corresponding stem bronchus it comes to occupy a position posterior (dorsal) and slightly lateral to the bronchus. The relation of the main trunks of the pulmonary vein to the bronchi is quite different; they are situated anterior (ventral) and mesial to their stem bronchi and in their ultimate distribution are situated as far removed from the bronchi as possible. I lay emphasis on "as possible" for in some situations they are found near the bronchi, but never as closely associated with it as in the artery. In one of the illustrations frequently used to show the relation of the pulmonary artery to the stem bronchi (that of Aeby) the position of the artery is correctly shown in the right lung, but in the left lung the position is reversed. The diagram given by Merkel is correct.

Keeping these relations in mind let us consider some of the practical applications of these injection masses to the anatomy of the lung, and for this purpose the lung of the pig and of the dog will be used. In Stereo 1, we have a stereoroentgenogram of the lung of a pig in which the pulmonary artery was injected with the vermilion starch mass and then distended with air. The heart has been removed and the free portion of the artery has been reflected anteriorly in order that the cannula and its clamp may not interfere with a clear picture of the bifurcation of the trachea and the main venous trunks which pass to the lower lobes of the lung. We recognize at once the dense shadow caused by the injected artery and we can follow its ramifications until they are lost just beneath the pleura. Lying on the mesial side of the artery in each lung we can recognize a hollow tube which, as we trace it anteriorly, joins its fellow and forms the trachea; these are the main stem bronchi. Situated on the mesial side of each bronchus, a third shadow, a trifle denser than the air-distended bronchi, can be seen; this is the main stem of the pulmonary vein. Because the artery has been filled with a distending injection it is pushed more to the lateral side of the bronchus than normal, and therefore throughout the greater part of its course appears to be situated at one side of the bronchus. It is, however, more closely applied to the bronchus than the vein, which shows an appreciable space between it and the bronchus throughout its entire course. The angle at which these three vessels enter the hilum of the lung differs on the two sides; on the right side the bronchus and artery enter the hilum pulmonis at a more acute angle than on the left side. The interweaving of the artery, bronchus, and vein which shows so distinctly in the lobus medius and the lobus superior of the right lung and in the lobus superior of the left lung is quite different from the hazy, smoky areas which are present in the early stages of tuberculosis.

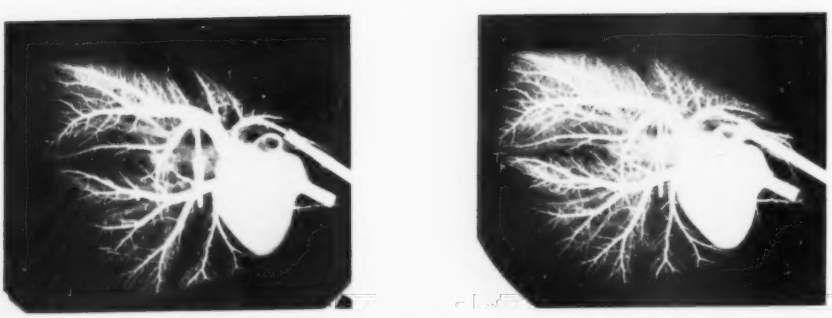
In Stereo 2, we have a stereoroentgenogram of the lung of a pig in which the pulmonary vein of the left lobus inferior was partially injected with a thick ultramarine blue starch mass and then distended with air. The pulmonary vein can be clearly seen situated anterior and mesial to the main stem bronchus. This relation, to one who is not familiar with the architecture of the lung, is not so apparent in the preceding stereo. The pulmonary artery, because of its position and because it is uninjected, is not easily recognized; but if the walls of the stem bronchi, especially that of the right lobus inferior, be closely studied, it will be seen that the lateral wall is denser than the mesial wall, and if this density be followed forward it will be found to be the continuation of the main trunk of the pulmonary artery, which can be seen just beneath the point where the glass cannula which is inserted into the pulmonary vein is connected with the short piece of rubber tubing. The second ventral branch of the stem bronchus in the left lobus inferior also shows in a characteristic manner the same increased density. In the left lobus superior it is the conformation of the lobe and a thin sheet of connective tissue that occasion the apparent thickening of the lobus. This increased density of the lateral wall of the bronchus is frequently seen in stereos of the human lung, when from any cause (heart lesion) there is unusual distention of the pulmonary artery. In like manner, any lesion causing distention of the pulmonary vein may occasion an increased density of the mesial wall of the stem bronchus.



STEREO 1



STEREO 2



STEREO 3

The thesis has already been advanced that the bronchus and artery are closely related to each other, while the vein is as far removed from the bronchus as possible. In the left lobus inferior when the course of the veins is in a horizontal plane there can be seen, between the injected veins, less dense shadows. As these are followed towards the midline they are found to join the stem bronchus; these densities are occasioned by the lateral branches of the stem bronchus. We find, then, a vein between two bronchi or, better, a bronchus between two veins. As these branches are followed through all parts of the lobe the veins appear to change their relation to the bronchi. This is due to the natural curvature of the lung, a fact that is sometimes overlooked in studying roentgenograms of the lung.

In the middle zone (third) of the lobus inferior of the right lung there can be seen scattered along the bronchi circular areas which show increased density. These are usually explained as being occasioned by a bronchus of the third or fourth order extending directly towards or away from the observer. If these densities be carefully examined they will be found to be of larger size than adjoining bronchi and often irregular in their contour. That these densities are due to bronchi alone may be true in some instances; that in the majority of instances they are occasioned by cartilages of peculiar form, which may or may not show a small amount of calcification, will be brought out in a forthcoming publication by the author. These circular densities are not always seen in a horizontal plane, but, as for example in the right lobus superior, they may have an oblique position as regards the observer. Scattered along the right stem bronchus, densities, due to the supporting cartilages, can be recognized in the angle between the stem bronchus and its branches. With a little study these densities can be differentiated from that due to the pulmonary artery.

In Stereo 3, we have a stereoroentgenogram of the lung of a dog in which the pulmonary artery was injected with a vermilion starch mass and the pulmonary vein with an ultramarine blue starch mass. The uniform dense shadow is the artery; the less dense and finely granular shadow is the vein. The bronchi do not show, being obscured by the injection of both the artery and vein. The lung is rotated slightly to the right and the heart is displaced forwards in order that the main blood-vessels can be clearly seen. This brings the left pulmonary artery into a prominent position in the upper part of the stereo. The small artery clamp was used to close a leak which prevented the lung from being fully distended.

In studying this stereo it should be kept in mind that the position of the lung is different from that in the two preceding stereos. In this stereo the dorsal surface of the lung is directed obliquely towards the observer and the trachea is at the right; in the other two the dorsal surface of the lung is away from the observer and the trachea is at the top of the stereo.

SUMMARY

1. By the use of differential injection masses in the pulmonary arteries and veins the relations of these structures are plainly outlined by stereoroentgenograms.

2. Even though the pulmonary arteries be uninjected, they can be recognized in stereoroentgenograms as comparatively dense linear markings along the lateral wall of the bronchi. Under similar conditions the main venous trunk can be made out on the mesial side of the stem bronchus, but in its ultimate distribution its branches are not associated with the bronchi.

3. In reading X-ray plates care should be exercised not to mistake these linear markings for densities produced by pathological changes.

4. Ring-like shadows with sharp borders that appear along the bronchi are often due to the plane that the bronchi bear to the observer. When these ring-like shadows are broad, with irregular hazy borders, they are cast by bronchial cartilages.

5. This study suggests once more the importance of a knowledge of lung structure in interpreting densities cast on the X-ray plate.

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AN ELECTROMYOGRAPHIC STUDY OF CHOREA

By STANLEY COBB, M. D.

(From the Neurological Laboratory, Henry Phipps Psychiatric Clinic, The Johns Hopkins Hospital, Baltimore, Md.)

Graphic methods have been but little applied to the clinical study of neuromuscular phenomena; hence, our physiological conceptions of these conditions are vague. Chorea is one of the worst offenders. Most writers consider this disease from the endocarditic or infectious standpoint alone. Hertz,[1] in a paper on Babinski's second sign, and Wilson,[2] in his work on the lenticular nucleus and corpus striatum, have discussed some of the neurological problems, but even good clinical descriptions of the muscular movements are rare. Perhaps the best are by Osler,[4] Weir Mitchell[5] and Russell[6]. The paper by Gregor and Schilder[7] is the only one that shows graphic records of choreiform movements.

The string-galvanometer has been used in the study of the skeletal muscles by Piper,[8] who finds that when a muscle is voluntarily contracted a series of action-currents are recorded at the rate of about 50 per second as long as the contraction lasts. This rate takes into consideration only the main waves (*Hauptwellen*) and not the wavelets which are superimposed on the larger waves. Recently Forbes[9-11] has criticized and amplified this work. By referring to either of

these authors a detailed description of the methods may be obtained. In brief the technique consists of placing over the muscle to be studied a non-polarizable electrode which leads off the action-currents of the contracting muscle to the string of the galvanometer, the circuit being completed through another similar electrode on the skin near the first but not over a contracting muscle. The movements of the galvanometer string are recorded on a moving film in the same way as in making electrocardiograms. In fact an ordinary "heart station" apparatus can be easily adapted for making electromyograms.

In this way several cases of muscular contraction were studied: First, normal voluntary contractions; second, voluntary contractions affected by chorea; and lastly, involuntary choreic contractions. The results are tabulated in Table I.

TABLE I

Observation number	Name of patient	Diagnosis	Muscle from which record was taken	Character of contraction	Character of electromyogram	Rate of main waves per second	Total rate of main waves + wavelets per second	Approximate average potential of action-currents in millivolts
1	L. S. C.	Normal.	Gastrocnemius.	Voluntary.	Steady tetanus.	50	160	0.5
2	L. B. H.	Normal.	Flexor sublimis digitorum.	Voluntary.	Steady tetanus.	58	180	1.7
3	K. J.	Unaffected side in hemichorea.	Flexor sublimis digitorum.	Voluntary.	Steady tetanus.	62	120	1.3
4	K. J.	Unaffected side in hemichorea.	Flexor sublimis digitorum.	Voluntary.	Steady tetanus.	57	121	1.1
5	K. J.	Unaffected side in hemichorea.	Flexor sublimis digitorum.	Voluntary.	Steady tetanus.	60	107	0.9
6	K. J.	Unaffected side in hemichorea.	Flexor sublimis digitorum.	Voluntary.	Steady tetanus.	55	121	0.9
7	K. J.	Unaffected side in hemichorea.	Flexor sublimis digitorum.	Voluntary, unsteady.	Irregular tetanus.	69	115	1.5
8	N. K.	Chorea.	Flexor sublimis digitorum.	Voluntary, unsteady.	Irregular tetanus.	56	133	1.0
9	N. K.	Chorea.	Flexor sublimis digitorum.	Voluntary, unsteady.	Irregular tetanus.	55	102	0.8
10	N. K.	Chorea.	Flexor sublimis digitorum.	Voluntary, unsteady.	Irregular tetanus.	58	118	0.8
11	I. M. R.	Chorea.	Flexor sublimis digitorum.	Voluntary, unsteady.	Irregular tetanus.	50	104	0.5
12	I. M. R.	Chorea.	Flexor sublimis digitorum.	Voluntary, unsteady.	Irregular tetanus.	52	114	0.6
13	E. S.	Chorea.	Flexor sublimis digitorum.	Voluntary, unsteady.	Irregular tetanus.	56	110	0.7
14	E. S.	Chorea.	Flexor sublimis digitorum.	Voluntary, unsteady.	Irregular tetanus.	58	116	0.7
15	E. S.	Chorea.	Flexor sublimis digitorum.	Involuntary.	Short tetanus.	66	124	0.5
16	E. S.	Chorea.	Flexor sublimis digitorum.	Involuntary.	Short tetanus.	74	101	0.3
17	N. K.	Chorea.	Flexor sublimis digitorum.	Involuntary.	Short tetanus.	58	130	0.8
18	N. K.	Chorea.	Flexor sublimis digitorum.	Involuntary.	Short tetanus.	58	105	1.0
19	N. K.	Chorea.	Flexor sublimis digitorum.	Involuntary.	Short tetanus.	60	120	0.6
20	I. M. A.	Chorea.	Flexor sublimis digitorum.	Involuntary.	Short tetanus.	72	120	0.2
21	I. M. A.	Chorea.	Flexor carpi radialis.	Involuntary.	Short tetanus.	72	130	0.2
22	M. F.	Chorea.	Flexor sublimis digitorum.	Involuntary.	Short tetanus.	50	92	0.7
23	M. F.	Chorea.	Flexor sublimis digitorum.	Involuntary.	Short tetanus.	50	90	0.8

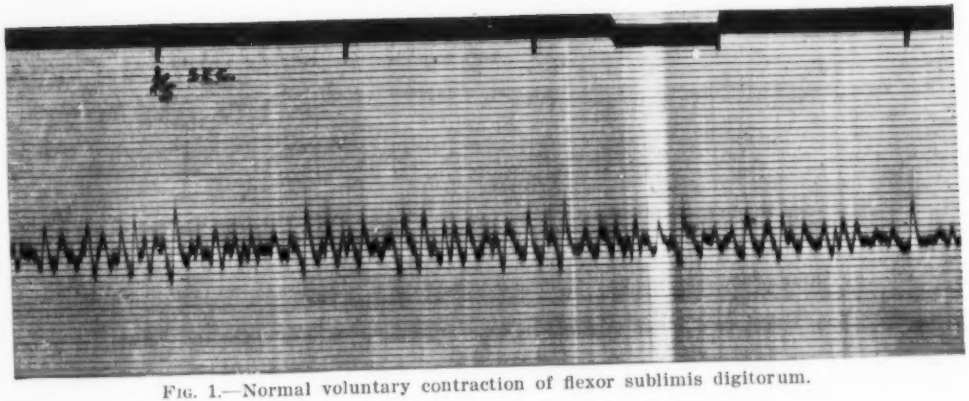

FIG. 1.—Normal voluntary contraction of flexor sublimis digitorum.

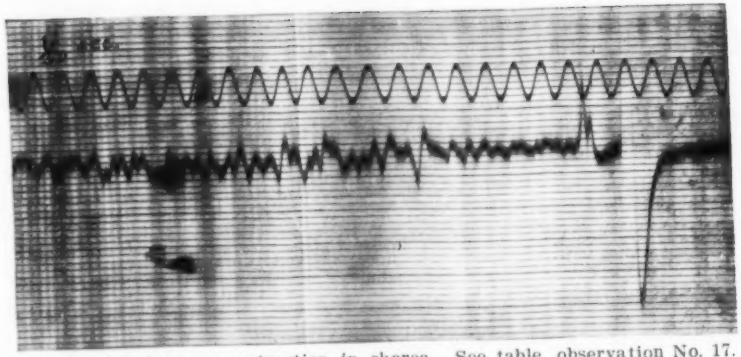

FIG. 4.—Involuntary contraction in chorea. See table, observation No. 17.

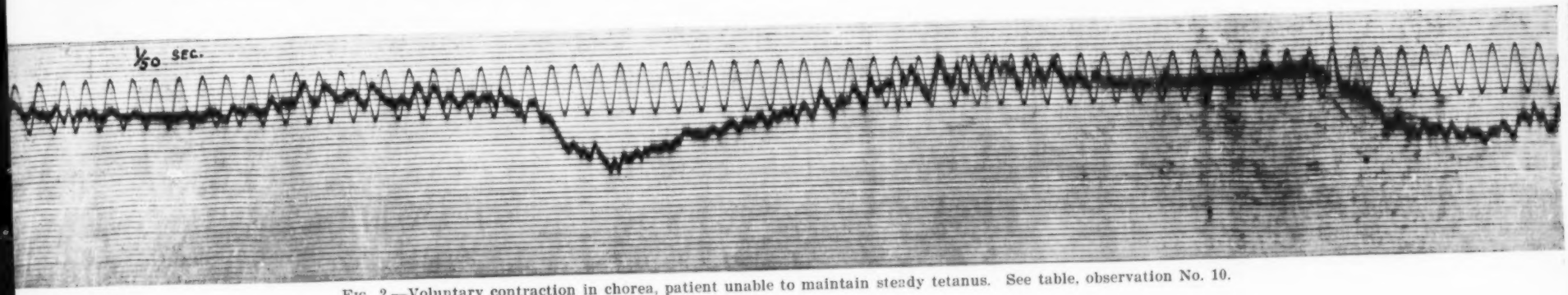

FIG. 2.—Voluntary contraction in chorea, patient unable to maintain steady tetanus. See table, observation No. 10.

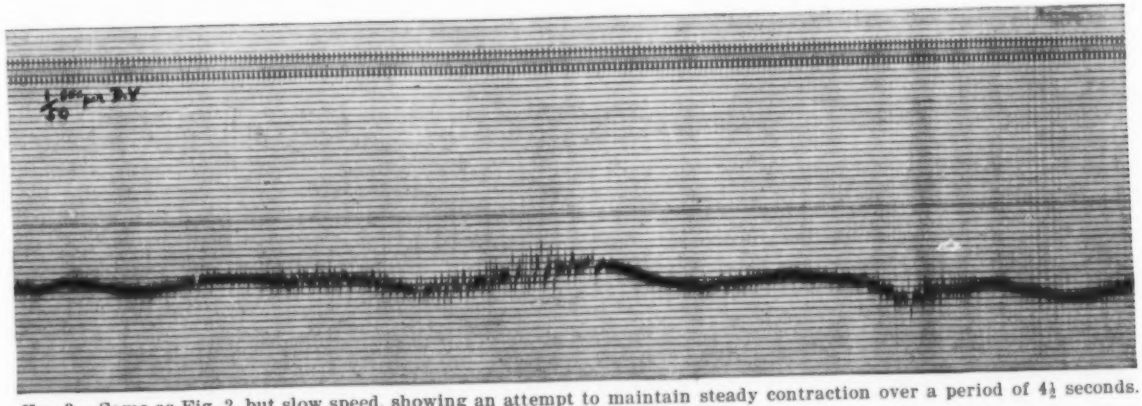

FIG. 3.—Same as Fig. 2, but slow speed, showing an attempt to maintain steady contraction over a period of 4½ seconds. See table, observation No. 11.

DISCUSSION

The tabulation of electromyographic records, as shown in Table I, shows that there is remarkably little qualitative difference between the action-current picture of a voluntary muscular contraction (Fig. 1)—whether it be in a normal or in a choreic individual—and that of an involuntary choreic movement (Fig. 4). Averaging the first six observations, those on *normally innervated muscles,* we get 57 main waves and a total of 135 if the wavelets are counted also. The average of the next eight observations, on *voluntary contractions of muscles affected by chorea,* gives the figures 57 and 113, respectively; while the records of *involuntary contraction,* nine in all, average 62 main waves and 123 total count per second. Quantitatively the normal voluntary contractions average 1.1 millivolts for an action-current, the voluntary contractions of affected muscles average 0.8 millivolt, and the involuntary contractions only 0.5 millivolt. This is what one would expect from the weakness clinically observed in these cases.

Gregor and Schilder give records from four cases of chorea, in which the rate of action-currents for voluntary contractions averages 54 per second, and for involuntary twitches 43 per second. This lower rate for the involuntary contractions is explained as possibly due to "a different localization for voluntary and for choreic movements, because in cortical innervation a rate of less than 50 per second is seldom found." It has been shown by Forbes and Rappleye[11] that the rate of action-currents in a muscle is dependent on the physiological state of that muscle; hence, "innervation" as used by Gregor, Schilder and Piper must be considered an erroneous term, for they seem to believe that each action-current represents a wave of nerve impulse. This subject has been further discussed by me in a paper on ankle clonus.[12] The fact that Gregor and Schilder found fewer action-currents per second in choreic twitches than in normal contractions may be due simply to the smaller amplitude of the waves registered on the film. The observations here published show that there is less electrical discharge in the weak contractions of a choreic movement than in the strong voluntary contractions (see Table I); hence, it may be gathered that the resistance of the patient might be enough to prevent any but the larger action-currents from registering. This should be taken into consideration and the apparatus readjusted when weak contractions are being recorded.

It seems therefore that the action-current pictures for voluntary and for choreic movement are essentially similar, except for their duration. Voluntary contractions are maintained over long periods, whereas choreic twitches may be as short as one-tenth of a second and show only four action-currents[7] (Fig. 15); but usually they last from two-fifths to four-fifths of a second, occasionally longer. Wherein lies the difference, then, between normal and choreiform movements? Most authors speak of the abnormality as a lack of co-ordination. Church and Peterson[13] mention the "relaxation or sudden increase of muscular tension" during voluntary contraction; whereas, Dr. L. F. Barker well describes this in his clinics as a "failure of the ability to maintain tonic contraction." Just this point is illustrated by Figs. 2 and 3, where the patient was ordered and urged to grip the dynamometer steadily, but could not do so. The tracing shows variations in the size of action-currents, and in places complete failure of the action-currents. The slow undulations of the whole line are explained by the squirming of the wrist and arm coincident with the effort to grip, causing shifting of the leading-off electrodes on the skin.

In this connection it is interesting to turn to the work of Wilson[3] (p. 483) on the corpus striatum, where he holds that this center is autonomous and exercises a "steadying influence" on the final common path of the pyramidal system via the lenticulo-rubro-spinal projection system. So it may be that in this form of chorea the "steadying influence" is lost, and with it the ability to maintain a steady contraction.

These electromyographic observations, therefore, seem to bring evidence which is of value in understanding the physiology of involuntary movements and the pathology of chorea. It is in the hope of stimulating others to study their neuromyopathic cases by this simple method, that this brief note is published.

CONCLUSIONS

1. Choreiform movements give an electromyogram similar to that of a short, normal, voluntary muscular contraction.

2. The inability to maintain voluntary contraction is clearly shown in the electromyograms.

3. Weakness of muscular contraction is shown electromyographically by the lessened electrical discharge.

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A PHARMACOLOGICAL APPRECIATION OF A BIBLICAL REFERENCE TO MASS POISONING, II KINGS IV, 38-41*

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INTRODUCTORY

The Book of Books has played and still plays such an important rôle in the history of mankind and the history of civilization that any contribution conducing to a better understanding or appreciation of it should be welcomed. In the present paper I wish to discuss a Biblical passage which is of more than ordinary medical historical interest. No apology need therefore be made for presenting it before this distinguished Society for the study of the history of medicine.

The particular passage to which I am referring is in the Second Book of Kings, Chapter IV, verses 38 to 41 inclusive. It describes the accidental poisoning of a band of prophets and the means employed by their leader, the prophet Elisha, in combating it. This passage is of especial interest from the pharmacological and toxicological points of view. The narrative reads as follows:

And Elisha returned to Gilgal: and there was a famine in the land; and the sons of the prophets were sitting before him; and he said unto his servant, Set on the large pot, and seethe pottage for the sons of the prophets.

And one went out into the field to gather herbs, and found a wild vine, and gathered thereof *Paqqû'ôt*, his lapful, and came and shred them into the pottage; for they knew them not.

So they poured for the men to eat. And it came to pass as they were eating of the pottage, that they cried out, and said, O thou man of God, there is death in the pot! and they could not eat thereof.

But he said, Then bring meal. And he cast it into the pot; and he said: Pour out for the people that they may eat. And there was no harm in the pot.

The points of query suggested by the above passage and calling for elucidation are, firstly, what is meant by *Paqqû'ôt*: secondly, what are the pharmacological properties of the same; and thirdly, the most interesting of all, what can we say of the antidote here employed in the light of modern science? In order to shed light on these questions, it was necessary not only to gather, sift, and analyze a good deal historical, philological, archæological, and botanical data, but also to perform a number of original pharmacological and toxicological experiments. The results of these inquiries and experiments we shall now proceed to describe.

ON THE MEANING OF PAQQÛ'ÔT

The Hebrew word *Paqqû'ôt* is rendered in the authorized version as "wild gourds" which, of course, may mean anything or nothing. All Biblical scholars and students of comparative philology, however, are agreed that the word *Paqqû'ôt* must mean either the *colocynth* or *elaterium* fruit. The etymology of the word, from a root *paqa'*, to burst or to break open, may apply appropriately to either one. *Ecballium elaterium* or the "squirting cucumber" owes its name to the peculiar character of its fruit which bursts open when ripe, ejecting the seeds mixed with a mucilaginous liquid. The colocynth fruit, when ripe and dry, is also easily burst open on the slightest touch. Professor Haupt suggests that the root *paqa'*, to burst or break through or open, may also refer to the drastic effects of the drugs, both of which, as is well known, are violent purgatives and may produce vomiting. (*Cf.* the German word *brechen*, to vomit). The Septuagintal rendering *tolype* refers to the round fruit of *Citrullus colocynthis*. The Vulgate has *colocynthides* (*Cf.* Pliny, XX, 14).

While the term *Paqqû'ôt* may from the etymological point of view denote equally well the colocynth or elaterium fruits, there is other evidence, botanical and archæological, which seems to point to the colocynth as the correct translation. *Ecballium elaterium* (in Arabic, *kithâ el himâr*) is a common plant in Mediterranean countries, but it could not with any propriety, as pointed out by Post,[1] be called a vine, for it is destitute of tendrils. According to Baillon it is "une herbe couchée sans vrilles"—a decumbent herb, without tendrils.[2] The *Citrullus colocynthis*, on the other hand, is a true vine growing prostrate on the ground, but trailing by means of its powerful tendrils over shrubs and herbs. This plant is also common in the Jordan valley, but is rare in the hill country of Ephraim; so that the men who gathered it mistook it for another plant of the same family, the *Cucumis prophetarum*, or globe cucumber, common in Samaria.

Still further evidence suggesting that *Paqqû'ôt* or wild gourds denotes the colocynth is the fact that we find the same term applied to the architectural ornaments mentioned in the Bible in connection with the Temple. In I Kings VI, 18, the word *p'qu'im* or colocynths is mentioned as an ornamental design in the interior woodwork of King Solomon's Temple; and in I Kings VII, 24, the same word is used to designate the ornaments encircling the molten sea or great brazen cistern in the Holy Temple. The elegant orange-shaped fruit of the colocynth plant lends itself well for ornamental purposes, whereas the small olive-shaped fruit of the *Ecballium elaterium* is by no means so beautiful or attractive.[3,4,5,6]

What do we know in regard to the poisonous properties of either the colocynth or elaterium? Before proceeding to discuss the toxicology of these plants it may be well to describe briefly their physical and chemical characters.

PHARMACOGNOSY

Both the colocynth and the elaterium plants belong to the family of the Cucurbitaceæ or pumpkin family. The colocynth fruit, *Fructus colocynthidis*, or the English *bitter apple*,

* Read before the Historical Club of The Johns Hopkins Hospital, December 2, 1918.

and German *Colocquinthe,* is the fruit of the plant *Citrullus colocynthis,* a slender scabrous plant with a perennial root, a native of warm and dry regions in the Old World. It is found in the Mediterranean regions, in Arabia, Syria and some of the Greek islands. (Fig. 1.) It grows in immense quantities in upper Egypt and Morocco, and is also found in some parts of Spain and Portugal. The plant bears yellow monœcious flowers, deeply lobed leaves and well-developed tendrils which enable it to trail over other plants. The fruit, which is globular in shape, resembles an orange and has a smooth, marbled-green surface, being from 5 to 10 cm. or from 2 to 4 inches in diameter. For medicinal purposes, the colocynth fruit is dried in the sun, then peeled, and is sold in this form on the market. The pulp is white, very light and spongy and is readily separable longitudinally into three carpels, each containing numerous flat, ovate, white or light brown seeds. It is the pulp which is purgative in its nature. The seeds are not laxative at all and are said to be used in some parts of Africa for food.[7] The active constituents of the colocynth fruits are at least two: one being the glucosid (?) *colocynthin,* having the empirical formula $C_{56}H_{84}O_{23}$, from which *colocynthein,* may be obtained by hydrolysis; the other is a closely related body named *colocynthitin.* Both of these principles are drastic purgatives.[8]

FIG. 1.—Citrullus Colocynthis Arn.

The elaterium fruit comes from the *Ecballium elaterium* Rich. (Momordica elaterium L.), a course, hispid fleshy decumbent plant *without tendrils,* having a thick white perennial root. It is also common throughout the Mediterranean region, extending eastward as far as Southern Russia and Persia, and westward to Portugal. The fruit is ovoid and oblong and nodding, about 1.5 to 3 cm. long, with numerous short prickles terminating in white elongated points. It is attached by a long scabrous peduncle, is fleshy and green while young, becoming slightly yellowish when matured. It is three-celled and contains numerous oblong seeds lodged in a very bitter succulent pulp. The fruit when ripe separates suddenly from the stalk on the slightest jarring and at the same moment the seeds and juice are forcibly expelled from the aperture left by the detached peduncle—hence the name "squirting cucumber" (Fig. 2.)

FIG. 2.—Ecballium Elaterium.

Several active principles have been isolated from the elaterium, the principal one, elaterin, being a crystalline body with a formula, $C_{20}H_{28}O_5$. Other constituents described are *hydroelaterin, prophetin* and *ecballin* or *elateric acid.*[9] Both the colocynth and elaterium plants have been known from remote antiquity, and are mentioned by ancient writers, Pliny, Dioscorides, Theophrastus and others.[10,11,12,13]

TOXICOLOGY

Colycynth and elaterium are well known in therapeutics as powerful or drastic purgatives. Even small doses of these drugs sometimes produce great irritation of the intestines. It will be remembered that colocynth is a constituent of the official compound cathartic pill, and elaterium has been named by one of the older therapeutists "the most potent purgative known to medicine." Slightly larger doses of the crude drugs, as well as of their active principles, produce a dangerous enteritis; and still larger doses act as violent poisons, leading to death.

The poisonous nature of these drugs was well known in the Orient. C. M. Doughty ("Travels in Arabia Deserta," Cambridge, 1888, vol. i, p. 132) says of the *Citrullus colocynthis:* "To human nature it is of so mortal bitterness that

little indeed, and even the leaf, is a most vehement purgative. They say it will leave a man half-dead, and he may only recover his strength by eating flesh meat." [14]

Kobert [15] states that 4 gm. of colocynth pulp are fatal to human beings, and even smaller doses will produce vomiting, bloody stools, anuria, collapse, delirium and convulsions. Lewin [16] gives 5 mg. of elaterin or 50 mg. of elaterium as the toxic dose for man and 60 mg. of elaterium as having produced death.

Von Jaksch [17] regards doses of 30 to 50 mg. of elaterin as very poisonous. Craig [18] reported death following the adminstration of two-fifths of a grain of the crude drug; and other writers emphasize even more strongly the dangers of this drastic purgative.

Poisoning with colocynth has, on the whole, been reported more frequently than with elaterin, possibly because the bitter apple has been employed to produce abortion.

Lewin mentions a case of fatal poisoning from 0.3 gm. of colocynth pulp. Blyth [19] reports two similar cases. Christison [20] reported the death of a young woman after one and a half teaspoonfuls of the powdered pulp. Rogers [21] mentions a fatal case after less than 60 grains of the powder; and other cases of poisoning are mentioned by Tidy,[22] Rolfe [23] and others.

The symptoms of poisoning by both colocynth and elaterium described by various authors are those arising chiefly from irritation of the gastro-intestinal canal. Vomiting, bloody stools, severe colic, collapse and convulsions, followed by death, constitute the general course of the intoxication. In some cases, symptoms referable to intense irritation of the kidneys are encountered.

The pathological findings reported describe an intense congestion of the stomach and intestines with ecchymoses and bloody sero-fibrinous exudates with adhesions. In more protracted cases, more or less extensive peritonitis with matting of the intestines and congestion of the kidneys, liver and spleen, have been noted. The lumen of the intestines may actually be obliterated by the fibrinous exudate and adhesions of the intestinal walls.

TOXICOLOGICAL EXPERIMENTS

In order to study the symptoms of colocynth and elaterium poisoning more in detail, and in order to visualize better exactly what took place in the case of poisoning which we are discussing and especially in order to determine the value of the antidote employed in that case, the author has performed a number of toxicological experiments on dogs. In connection with these experiments, it was interesting to note a toxic symptom, which is not mentioned by most authors on the subject and not emphasized sufficiently by those who have noted it, and which is especially interesting in connection with the passage before us.

In my experiments I made use of infusions of either colocynth apples or the crude elaterium which can be bought on the market. The drugs were roughly cut up or ground up and infusions were made by boiling them in ordinary tap water in a casserole with or without the addition of a little common table salt. This corresponded roughly to the conditions obtaining in the case of the prophets. After the mixture had been boiled for half an hour or longer, the resulting infusion was strained through coarse cheese-cloth and was administered cold to the dogs through a stomach-tube. The symptoms following the administration of such an infusion of colocynth apples may be divided into two groups, the primary and the secondary. The most striking primary symptom consisted of a profuse salivation which occurred even when the drugs were introduced through the stomach tube, enough of the infusion coming in contact with the mucous membranes of the mouth when the stomach tube was withdrawn to produce this irritation. The salivation was very intense; the animals foaming at the mouth more than after a dose of pilocarpin. This primary symptom, so little emphasized by other writers, is quite sufficient to account for the exclamation of the victims, "There is death in the pot!" Vomiting was occasionally also noted soon after administration of the infusions of colocynth. An almost precisely similar primary salivation followed the introduction of an elaterium infusion into the animal's stomach. Following the primary salivation and occasional vomiting, the secondary or later symptoms of colocynth or elaterium poisoning did not come on until an hour or two later. These began with violent purging, soon followed by bloody stools, collapse and depression. After large doses of either drug (the quantities to be described below) the animals were generally found dead on the following day. At autopsy, the anatomical findings were: Intense inflammation of the stomach and especially the intestines, with bloody exudate and adhesions; occasional peritonitis; intense congestion of the liver and the kidneys.

In view of the marked irritation and destructive lesions just described, it is especially interesting to turn our attention now to the most perplexing feature of our narrative, namely, the antidote administered or employed by the prophet Elisha to antagonize the effects of the poison.

ON FLOUR AS AN ANTIDOTE

In order to ascertain whether the method employed by Elisha can be explained on a natural basis the author in a purely scientific and impersonal manner carried out two series of experiments: In the one series, a number of dogs were given colocynth or elaterium infusions straight, that is, without the admixture of any other substance. In the other series exactly the same quantities of the infusions in proportion to the animal's weight, or even larger doses of the poisons were administered after previous admixture of ordinary corn and wheat flour. The results of these experiments are very interesting and enlightening and may be best illustrated by the following protocols:

Exp. V, October 7.—**White dog weighing 7.1 kilos. Five colocynth apples, weighing together 40 gm., were cut up and boiled with 750 c. c. of tap water. The mixture was boiled until the volume was reduced to 500 c. c. It was then strained through coarse cheese-cloth and one-half of the infusion, or 250 c. c., were given to the animal through the stomach tube, about 2 p. m. Immediately after the removal of the stomach tube the dog**

became most violently salivated, foaming and frothing at the mouth so that the whole cage was bespattered with saliva. A little of the infusion plus stomach contents was vomited out. Two hours later the animal was violently and repeatedly purged, the stools being fluid and tinged with blood. During the night, the frequent stools continued and assumed a much more bloody character. On the following morning, the animal was found dead. The autopsy revealed a violent congestion of the stomach, especially of the small intestine. The intestines were filled with a bloody exudate and in some places were stuck together by fibrinous adhesions. The liver also was congested and the kidneys to a very marked degree.

Exp. VI, October 7.—Brown dog weighing 6 kilos. Forty gm. of colocynth apples were cut up and mixed with 60 gm. of flour (equal parts of wheat and corn) and 1000 c. c. of tap water. The mixture was boiled until the total volume was reduced to 500 c. c. It was then strained, in order to remove the seeds and débris, through coarse cheese-cloth, and 250 c. c. of the broth were administered to the dog through a stomach tube exactly as in the preceding experiment, about 2.15 p. m. On removal of the stomach tube there was no vomiting and practically no salivation noted. About two hours later, the animal passed several normal stools, but no blood was noted in them; neither was there any blood noted in the stools passed during the night. On October 8, the animal was lying slightly depressed and still had diarrhœa, but ate the food offered it. On October 9, the animal was apparently completely recovered, running about in a lively fashion.

On comparing the two experiments described above, it will be seen that in the case of the dog to which the pure infusion of colocynth was administered, both the primary and the later symptoms of colocynth poisoning were very markedly developed, and in this respect differed from those noted in the other animal. The white dog was very profoundly salivated; indeed, the salivation was more marked than that noted by the author after any other poison. Violent irritation of the bowels very early manifested itself as indicated by the bloody stools; and the animal died within 18 hours.

In the dog to which the infusion of colocynth was administered together with flour the symptoms were not at all so striking. There was practically no salivation at all and no vomiting; nor did the stools indicate any violent irritation of the intestinal mucosa; and the animal recovered completely within two days.

Exactly similar results were noted in experiments with elaterium, as may be illustrated by the following two protocols:

Exp. VII, October 22.—White dog weighing 4 kilos. Five gm. of dried elaterium juice or exudate, obtained from the firm of Sharp & Dohme through the courtesy of Dr. H. D. Engelhardt, were pulverized in a mortar and then boiled for half an hour in 300 c. c. of tap water with the addition of a little common table salt. Of this mixture 150 c. c. were then introduced into the stomach through a stomach tube at about 11.30 a. m. Immediately after withdrawal of the tube, the animal became very much salivated. About 2 p. m. a black, bloody stool was passed. Repeated purgation occurred during the night and on the following morning the animal was found dead. An autopsy revealed anatomical lesions very much as in the case of colocynth poisoning, though perhaps more intense in degree.

Exp. VIII, October 22.—Brown dog weighing 5 kilos. Six gm. of dried elaterium juice or exudate were ground in a mortar and mixed with 15 gm. of flour and the mixture was boiled for half an hour with 300 c. c. of water. At 11.40 a. m. about 175 c. c. of the broth were introduced through the stomach tube into the animal's stomach. On withdrawal of the stomach tube there was no vomiting and practically no salivation. About two hours later, a yellow stool was passed and several other fluid but not bloody stools were passed during the night. On the following morning, October 23, the animal was found very much depressed, lying quietly in the cage and refusing food. On October 24, the animal was still depressed, but ate meat. On October 25, the animal was more lively and hopping about. October 27, the dog was practically in normal health.

In the case of the elaterium it will be noted again that the plain infusion was much more toxic when given alone than when administered mixed with flour broth. In the first case, salivation, bloody stools and death followed, whereas in the second case, although there were diarrhœa and depression, no salivation was noted, no violent irritation occurred and the animal eventually recovered.

DISCUSSION

To the superficial reader of the Bible and to a class of destructive critics who are prone to condemn any statement in that Book, which does not accord with their own personal subjective views, as an impossibility or a figment of the imagination or as a perversion of the original text, the results of the above investigations may appear unexpected and possibly even disappointing. To the truly unbiased scientific mind, however, which does not condemn or disbelieve anything, but only demands facts and proofs, the above experiments are not altogether surprising and the Biblical narrative which we are discussing does not appear at all improbable. In fact, the results of the experiments just described well agree with the teachings of modern chemistry and pharmacology. Recent advances in those sciences have revealed the very important rôle played in the physiological economy of animal organisms by the so-called "colloid" substances. It has been shown that an admixture of colloidal and even of non-colloidal but inert and inactive matter to various foods and drugs may profoundly influence their absorption and their action. Thus, for instance, Mendel and Lewis[24] in a paper on "The Rate of Elimination of Nitrogen as Influenced by Diet and Other Factors," have found that with a definite diet it is always possible to get a definite typical curve of nitrogen elimination. On the addition, however, of various inert or colloidal substances, such as minerals, vaseline, bone ash, filter paper, cork, agar-agar, etc., to exactly the same diet, the curve is entirely changed, and the rate of nitrogen elimination in such cases is greatly delayed.

Again, Fantus[25] and others have found that admixture of kaolin and other inert matter may greatly modify the action of strychnin and other poisons. It is, therefore, not entirely surprising to find that flour or "meal" should profoundly modify the action of the infusions of colocynth or elaterium and render them innocuous, and the popular first aid maxim to give flour in many cases of poisoning has a real rational basis. What the exact mechanism of this antagonistic action is, is not quite clear; but undoubtedly several factors are involved in the phenomenon. The colloid broth, in the first place,

hinders the absorption of the poison; secondly, the flour probably acts as a demulcent and protective to the intestinal walls; and thirdly, this substance must also exert some effect by virtue of its adsorptive properties. Whatever the exact mechanism of flour as an antidote may be, there can hardly be any doubt as to the plausibility of the Biblical narrative before us; and in the light of the experiments performed, the story, if not a miraculous one, certainly attests to the wonderful insight and wisdom and practical experience of the Seer Elisha.[26]

The author wishes to express his gratitude to Profs. Paul Haupt and D. S. Johnson, for valuable information received in the domains of Semitic Philology and Botany, respectively.

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